SMC-TR-93-61

AEROSPACE REPORT NO.
TR-0091(6940-05)-7

AD-A275 150

Proton Switches

DTIC
ELECTE
JAN 31 1994
S B D

1 November 1993

Prepared by

J. B. BLAKE and S. S. IMAMOTO
Space and Environment Technology Center
Technology Operations

Prepared for

SPACE AND MISSILE SYSTEMS CENTER
AIR FORCE MATERIEL COMMAND
2430 E. El Segundo Boulevard
Los Angeles Air Force Base, CA 90245

Engineering and Technology Group

APPROVED FOR PUBLIC RELEASE
DISTRIBUTION UNLIMITED

94-02894

AEROSPACE
RPORATION

0 3 1

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE
1 November 1993

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Proton Switches

5. FUNDING NUMBERS
F04701-88-C-0089

6. AUTHOR(S)
Blake, J. B. and Imamoto, S. S.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
The Aerospace Corporation
Technology Operations
El Segundo, CA 90245-4691

8. PERFORMING ORGANIZATION REPORT NUMBER
TR-0091(6940-05)-7

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Space and Missile Systems Center
Air Force Materiel Command
2430 E. El Segundo Boulevard
Los Angeles Air Force Base, CA 90245

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
SMC-TR-93-61

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maxirr n 200 words*)

An overview is given of the design and performance of two simple omnidirectional proton sensors included in the payload of the CRRES mission. These sensors measured the proton fluxes in the energy range of approximataely 20 MeV to 100 Mev.

14. SUBJECT TERMS
Proton detectors, Space radiation detectors, CRRES payload

15. NUMBER OF PAGES
6

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

Proton Switches

J. B. Blake* and S. S. Imamoto†
The Aerospace Corporation, Los Angeles, California 90009

THE proton switches (PS) are two omnidirection detectors, sensitive to protons (and heavier ions). The name proton switch has an historical origin. They were used in a mission 20 years ago (OV1-20PM) for turning on a high-power payload when energetic protons were present, and turning it off when the proton flux dropped below a preset value. In its first incarnation SPACERAD was to have been a simple, duty-cycled payload.

The PS detectors are Li-drifted silicon with a cubical shape, 3 mm on an edge. A uniform hemispherical shield is placed over the upper 2π solid angle; the rear 2π solid angle is shielded far more massively. The configuration is shown in Fig. 1. The detectors are connected to the usual preamplifier, amplifier, and discriminator electronic systems. The discriminator levels are chosen to be several times the energy which an electron can deposit in the detector. As a result, only protons and heavier ions are detected, and background caused by electron pileup is nil. The energy threshold is determined by the thickness of the hemispherical shield and, to a much smaller degree, by the discriminator thresholds. The hemispherical shields for the SPACERAD sensors were chosen to be 20 MeV and 50 MeV (for protons).

A zeroth-order estimate of the geometric factor is computed in the following way. The efficiency $\epsilon(E,E_B)$ is calculated from proton range-energy tables and geometric considerations, i.e., the path-length distribution converted to energy deposit for a given discriminator level E_B. The geometric factor is defined by the following expression:

$$\bar{\epsilon}\int_{E_l}^{E_u} e^{-E/E_0} = \int_{E_l}^{E_u} \epsilon(E,E_B)e^{-E/E_0}$$

where the subscripts l and u refer to the lower and upper limits of the energy channel. The lower level E_l is fixed by the shield and E_B is set by the electronic threshold. Therefore the integration given above is carried out for values of E_0 of geophysical interest and for a series of values for E_u. The value of E_u is selected such that the geometric factor is independent of the spectral index. Similar calculations have been carried out for power-law spectra; the results are much the same. Table 1 gives the geometric factor for the four PS channels for exponential spectra.

It is important to note the assumption that goes into the calculations of geometric factor and energy passband—that the spectral shape is either exponential or power-law and fixed over the entire energy range of integration. In the inner zone, it is conventional wisdom that the proton spectra are exponentials over a large energy range, cf. AP-8. In the case of solar-flare spectra, this assumption usually is not a good one. *The geometric factors and passbands are gross approximations only, and must be used with care.*

A conversion of count rate to proton flux can be made readily by using the large arrays of calculated values for $\epsilon(E,E_B)$; this must be done for quantitative work. (The calculated efficiencies as a function of energy are available from the authors.) However, the major purpose for including these two sensors in the SPACERAD payload was to provide guidance in the analysis of the data from the more sophisticated sensors—is there a penetrating proton background, about how large is it, and what roughly is the spectral shape? These purposes are well served by the information in Table 1.

It was noted above that these sensors have no electron sensitivity. However, they do show a very low count rate due to galactic cosmic rays. Since there are very few cosmic rays in the passbands of the proton switches, the major causes of these background counts are nuclear interactions in the detector itself and neutron-induced reactions in the detector where the neutrons are secondaries generated in the spacecraft. This low cosmic-ray background varies over the combined release and radiation effects satellite (CRRES) orbit because of the variations in geomagnetic cutoff.

Figure 2 is a line plot of the output of the two sensors for a partial orbit including the inner zone where the trapped energetic protons are found. The upper trace is for the sensor with the 20-MeV shield (lower energy threshold); the lower one for the 50-MeV shield (lower energy threshold). This figure clearly shows the sensor characteristics described above. Note the immunity to background counts from electrons; away from the broad peaks due to the inner zone protons only the very low residual galactic cosmic-ray background can be seen. It also is easy to see that near perigee (34,999–35,000 s), where many of the galactic cosmic rays are excluded by the Earth's magnetic field, the background rate indeed is significantly reduced compared to the background count rate seen elsewhere.

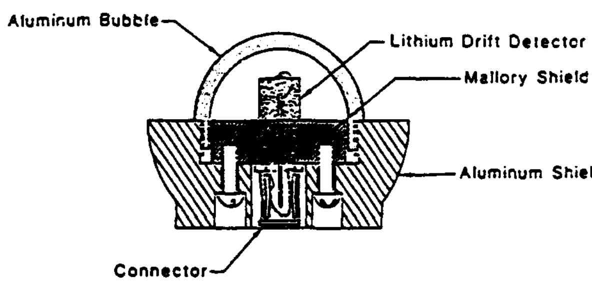

Fig. 1 A cross section of a proton switch sensor is shown with the key components labeled.

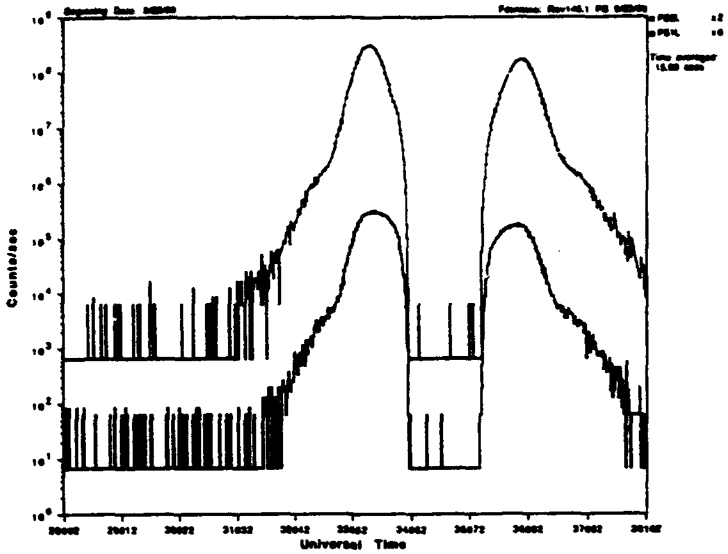

Fig. 2 Data from the low-threshold channels of the two proton switches are shown during the time period around perigee. Note that the top curve is multiplied by 100 in order to separate the two curves. Between ≈ 28,000 and 31,500 s the CRRES spacecraft was above the region containing the energetic protons, and the proton switches were counting cosmic-ray background. The two peaks result from the inbound and outbound legs of the CRESS orbit because the spacecraft goes below the radiation belts before reaching perigee. Note the very low background between the peaks (around perigee) where the geomagnetic field excludes much of the galactic cosmic-ray flux; thus the background count rate is reduced substantially in that region.

Table 1 Calculated approximate geometric factors and energy ranges

Channel identification	Energy range, MeV	Geometric factor, mm^2
PS2L	21–84	3.9
PS2H	23–51	2.6
PS1L	51–107	3.6
PS1H	51–77	2.7

Acknowledgment

This work was supported under Air Force Space Systems Division Contract FO4701-88-0089.

TECHNOLOGY OPERATIONS

The Aerospace Corporation functions as an "architect-engineer" for national security programs, specializing in advanced military space systems. The Corporation's Technology Operations supports the effective and timely development and operation of national security systems through scientific research and the application of advanced technology. Vital to the success of the Corporation is the technical staff's wide-ranging expertise and its ability to stay abreast of new technological developments and program support issues associated with rapidly evolving space systems. Contributing capabilities are provided by these individual Technology Centers:

Electronics Technology Center: Microelectronics, solid-state device physics, VLSI reliability, compound semiconductors, radiation hardening, data storage technologies, infrared detector devices and testing; electro-optics, quantum electronics, solid-state lasers, optical propagation and communications; cw and pulsed chemical laser development, optical resonators, beam control, atmospheric propagation, and laser effects and countermeasures; atomic frequency standards, applied laser spectroscopy, laser chemistry, laser optoelectronics, phase conjugation and coherent imaging, solar cell physics, battery electrochemistry, battery testing and evaluation.

Mechanics and Materials Technology Center: Evaluation and characterization of new materials: metals, alloys, ceramics, polymers and their composites, and new forms of carbon; development and analysis of thin films and deposition techniques; nondestructive evaluation, component failure analysis and reliability; fracture mechanics and stress corrosion; development and evaluation of hardened components; analysis and evaluation of materials at cryogenic and elevated temperatures; launch vehicle and reentry fluid mechanics, heat transfer and flight dynamics; chemical and electric propulsion; spacecraft structural mechanics, spacecraft survivability and vulnerability assessment; contamination, thermal and structural control; high temperature thermomechanics, gas kinetics and radiation; lubrication and surface phenomena.

Space and Environment Technology Center: Magnetospheric, auroral and cosmic ray physics, wave-particle interactions, magnetospheric plasma waves; atmospheric and ionospheric physics, density and composition of the upper atmosphere, remote sensing using atmospheric radiation; solar physics, infrared astronomy, infrared signature analysis; effects of solar activity, magnetic storms and nuclear explosions on the earth's atmosphere, ionosphere and magnetosphere; effects of electromagnetic and particulate radiations on space systems; space instrumentation; propellant chemistry, chemical dynamics, environmental chemistry, trace detection; atmospheric chemical reactions, atmospheric optics, light scattering, state-specific chemical reactions and radiative signatures of missile plumes, and sensor out-of-field-of-view rejection.